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Response to Report of Evaluation Working Group
National Data Broadcasting Committee

March 17, 1995

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Dear NDBC Member:

As you review the laboratory test results and consider the next steps to take in the development of standards for this new service, WavePhore considers it to be critical to highlight several key facts and issues, which are discussed in the attached "Response." When those facts and issues are considered, WavePhore is confident that the Committee's members will conclude that:

1. Testing of both systems should continue.

2. The additional testing should fully consider among other things: (a) the out-of-band emissions of Digideck's technology and (b) the compatibility of the two systems when used by the same broadcaster.

3. Reasonable improvements to both technologies should be permitted as the standards process moves forward.

WavePhore is not seeking to be the exclusive data broadcast standard. To the contrary, WavePhore believes that broadcasters and consumer electronics manufacturer will benefit from having as wide a data transmission pipe as possible. Receiver/decoders will be modular and can be easily plugged into consumer devices such as personal computers and televisions, so a single-technology standard is not critical. If both WavePhore's and Digideck's technologies are compatible and after thorough testing they each offer a technically viable and cost effective product, the NDBC should adopt a standard that facilitates broadcasters using either or both of the technologies.

SUMMARY

WavePhore Is Uniquely Prepared to Implement Data Broadcasting

WavePhore is the premiere proponent of data broadcasting. The Company has invested millions of dollars and years of effort in putting together all the many pieces needed to make data broadcasting a reality. During that time it has refined the technology, developed the software and the applications necessary for the creation and management of datacasting applications, and dealt with the real-world challenges of bringing datacasting services to market.

WavePhore's technology has been proven not to cause visible video or audio degradation in normal viewing circumstances during two years of extensive field experience.

WavePhore's technology has been proven to provide robust recovery of high-speed data in real-world field trials. With the added improvements expected in the next few months following the laboratory testing, WavePhore expects its technology to be robust under even the most unusually harsh conditions, such as were imposed in the tests by the Advanced Television Test Center ("ATTC").

WavePhore's technology can be used not just on television stations, but also on all other parts of an integrated distribution network that includes satellites, video microwave relays, video recorders, TV translators, and cable systems -- all key elements in marketing a data broadcasting system.

Digideck's System Presents Serious Risks That Preclude Its Adoption As A Standard At This Time

Digideck is a new company without apparent resources and with technology that is only in the prototype stage. As Digideck moves from prototype to production equipment, it is likely to encounter obstacles that will at a minimum require modifications that may reduce its performance.

Digideck's technology exhibits out-of-band emissions that may cause interference to adjacent Advanced Television channels.

Digideck has not demonstrated that its technology can be integrated into a complete network. Its technology does **not** work with programming transmitted by satellite or microwave relay and is **not** recordable.

Digideck's technology appears likely to require FCC approval for each type of transmitter that it modifies. Given the large variety of transmitters presently in use by broadcasters, obtaining such approvals would greatly complicate the initiation of data broadcasting. Differences in the manner in which the Digideck exciter operates with different transmitters will also make it difficult for a network (or for that matter, a group owner) to initiate data broadcasting on its numerous affiliates using Digideck technology.

WAVEPHORE IS IN A UNIQUE POSITION TO LAUNCH DATA BROADCASTING

WavePhore's Resources and Experience. WavePhore, Inc. is a research and development company founded in 1990 to develop high-speed data broadcasting equipment. Since 1990, WavePhore has invested over $20 million dollars in developing and promoting data broadcasting, and has raised $34 million dollars towards that effort

WavePhore's promotion of data broadcasting has included a major role domestically and internationally in educating broadcasters and equipment manufacturers about data broadcasting. Beginning at the NAB Future Forum in January 1993 in Naples, Florida, WavePhore has been working with NAB and others to demonstrate the potential of data broadcasting. The establishment of the NDBC is a direct result of that effort. Since then, dozens of major broadcasters and equipment manufacturers, including NBC, Chris-Craft, Hearst, Cox, Toshiba, and Phillips have been briefed and seen demonstrations on data broadcasting at WavePhore's facilities, and WavePhore has spent hundreds of thousands of dollars in direct support of NAB's efforts (principally overseas) to get out the word about datacasting.

WavePhore has also been the principal proponent of high-speed data broadcasting at the Federal Communications Commission. WavePhore filed a request for declaratory ruling in late 1993 to clarify that TV licensees have the legal authority to provide data services on an ancillary basis as long as the data transmissions do not degrade the broadcaster's basic video service or cause harmful interference to other users of the spectrum. As a result of WavePhore's efforts, the Commission is preparing a Notice of Proposed Rulemaking that should be released within the next few weeks and is understood to propose substantial flexibility for broadcast licensees to provide data services.

Integrated Solutions. WavePhore's most extensive operations are in Canada where its subsidiary, WavePhore Canada, Inc., has integrated its TVT1/4 products into a communications and applications development platform called "Information Skyway." The Skyway system is broadcasting data through up to 10 VBI lines as well as the full 384 Kbps capacity of the current TVT1/4 system. WavePhore Canada has an exclusive contract with the Canadian Broadcasting Corporation for the distribution of multimedia data to business and consumer users.

Initial applications that are currently operating include the updating of time sensitive travel package inventory files for travel agents, an electronic clipping service that provides articles from 15 newspapers on selected topics, and a service that provides newspaper headlines and articles to blind readers equipped with special Braille or audio response terminals. An active marketing program is in progress offering content to information users through both VBI and the TVT1/4 technology.

WavePhore's Skyway system includes not only a complete communications system for receiving, scheduling and routing of digital data from multiple customers, but also a Windows NT application development platform. This technology facilitates the development and tailoring of end user applications to the multimedia datacasting environment, which had previously been a roadblock to the acceptance of data broadcasting technology. This communications management

and application development front end represents over two years of testing, development, and real-world operations.

The success of the Skyway system demonstrates WavePhore's ability to put together an integrated solution to providing data broadcast services, one that solves such problems as data storage, addressability, encryption, metering and content filters.

Field Trials. WavePhore has engaged in extensive field testing of its TVT1/4 system in the United States. In Phoenix, the TVT1/4 system was originally tested on Channel 12, and has since been tested five days a week for twenty months on Channel 3. The technology was in constant use for nineteen months on Channel 45, a Chris-Craft station, and Chris-Craft personnel have participated in that testing process. The TVT1/4 system was demonstrated in the NAB Science and Technology area during the 1994 NAB Convention in Las Vegas, using KTNV, Channel 13. Arrangements are being made for a similar test during the 1995 NAB Convention. WavePhore is presently, with the FCC's approval, working with WFLA(TV) in Tampa, Florida to establish a weather datacasting operation to provide critical hurricane and other weather information to various organizations in the surrounding area.

In non-broadcast applications, WavePhore has utilized its TVT1/4 technology for nineteen months on Arizona State University's ITFS system, and operated for nine months on TCI's Scottsdale cable system. In addition, the TVT1/4 system has been used in short tests in TCI's Tulsa cable system, which included microwave and fiber optic links, and in a demonstration test over the Congressional cable system in Washington, D.C.

The TVT1/4 technology has also been used with MCI's Phoenix uplink many times, and WavePhore has transmitted over satellite in the video signals of both WTBS and WGN. WavePhore presently has a working arrangement with Channel America -- a television satellite program provider -- to piggyback on their signal so as to provide WavePhore with a nationwide multimedia datacasting footprint.

International Efforts. In addition to the Canadian systems, WavePhore is in the process of establishing a Japanese subsidiary and is in negotiations or discussions with numerous Japanese broadcasters, content providers, trading houses, equipment manufacturers, and financiers to establish data broadcasting in Japan. WavePhore is presently working with the Japanese Ministry of Posts and Telecommunications regarding approval of WavePhore's data broadcasting system in Japan.

In Europe, Siemens is serving as the European distributor of WavePhore's technology. The TVT1/4 technology has been used to send data over an Italian television network utilizing the PAL transmission system without difficulty. Tests with the PAL transmission system have also been performed with success in Switzerland.

WavePhore is preparing for testing and is actively promoting the development of data broadcasting in Russia, Mexico, and New Zealand. NTSC datacasting tests have already been conducted in Taiwan.

WavePhore has participated in a working party of ITU-R Study Group 11 (Television) dealing with auxiliary services and has submitted a report, through the U.S. National Committee of the ITAC-R, to the working party as a U.S. contribution describing WavePhore's technology. The report has been accepted by the working party, which is the first step in the adoption of an international standard by the ITU-R.

Absence of Video Degradation. Video degradation is not a problem for broadcast use of TVT1/4 in normal operations. Millions of viewers have watched broadcast signals for many hours with WavePhore's technology in use -- including thousands of television professionals at the NAB Convention -- without noticing the injection of data. The laboratory testing by ATTC confirmed this, showing that only under the most stressed conditions was any degradation perceptible to expert viewers. In any event, in an effort to reduce any possible picture degradation under even the most extreme viewing conditions, WavePhore is planning to replace the existing low pass LC filter used in the encoder with a custom-designed SAW filter which should minimize the chroma smearing that was perceptible under stressed laboratory conditions.

Robustness. As a result of the ATTC tests, WavePhore is also planning to improve its robustness in hostile RF environments. The system tested by the ATTC was a relatively mature product that has experienced few difficulties in operating under real-world conditions. However, when it was subjected to the unusually intense multipath and impulse noise created in the laboratory, the decoder did exhibit some data decoding problems. WavePhore has examined the errors and determined that the problem did not involve either the encoding or transmission of the data, but instead involved only the data decoding process. The system tested by the ATTC relied on the video synchronization signal for deriving its data timing. The multipath and impulse noise created in the laboratory affected the edges of the horizontal synchronization pulses, thereby causing mis-timing of the data decoding process.

While WavePhore has found the real-world existence of such interference to be relatively unusual, this sensitivity to interference can be fixed, and WavePhore is presently implementing that remedy. The revised system will eliminate any interference sensitivity by deriving the data timing directly from the data signals, independent of the video synchronization. In fact, the revised system will derive both the bit timing and the carrier phase from the data signal directly, using advanced techniques commonly used in computer modems and satellite communications systems. The bit timing will be recovered using a combination of DSP techniques, including early/late gate loops, conventional phase-lock loops with nonlinear elements, and adaptive equalizer coefficient analysis. These techniques will continually cross-check each other to ensure reliable timing recovery. Carrier tracking will make use of the adaptive equalizer error signal in conjunction with a multi-bandwidth phase-lock loop, again ensuring accurate carrier recovery under even the most severe conditions. Along with other circuitry refinements being introduced to the system, the revised system will use data interleaving and deep forward error correction to ensure that any data errors which might still occur are immediately caught and corrected.

WavePhore's own field tests and the analysis of the laboratory tests done by Cohen, Dippell & Everist show that WavePhore's technology in its present form provides robust data recovery under most conditions likely to be found in the market, at least out to a television station's Grade B contour While WavePhore intends to continue to improve its product as

described above, even in its present form the system is reliable for most fixed site and portable applications.

Chip Set. These improvements, including increased robustness, are part of WavePhore's on-chip consumer product that is expected to be available within 6-9 months and will be made available, in accordance with EIA guidelines, under reasonable terms and conditions that are demonstrably free of any unfair discrimination.

Recordability. One important area in which WavePhore believes the ATTC report is in error regards the recordability of the video/data signal to allow delayed transmission or recovery of the data. WavePhore, prior to the ATTC testing, had successfully recovered data from wideband digital tape machines at Channel 8 in Phoenix. The ATTC's conclusions regarding the non-recordability of the TVT1/4 system are at variance with WavePhore's own experience. In order to check the ATTC's conclusions on recordability, WavePhore recently rented a D-2 recorder and recorded and recovered data successfully, just as it had in its earlier tests. An examination of the recording made demonstrated that the recorder had indeed captured the TVT1/4 data, and WavePhore was able to decode the data from these tapes with no bit errors in the fifteen minute recording. WavePhore therefore urges that further testing of the TVT1/4 system examine the system's recordability, which WavePhore believes is an important characteristic lacking in the Digideck system.

THE DIGIDECK SYSTEM PRESENTS SERIOUS RISKS THAT PRECLUDE ITS ADOPTION AS A STANDARD AT THIS TIME

Prototype Technology. The biggest risk presented by the Digideck technology is the fact that it is only a prototype. Thus, even if Digideck had all of WavePhore's experience and resources, the technology it proposes is still just that -- a technology. Digideck is literally years behind WavePhore in terms of producing a consumer product, and the path to finished product is strewn with pitfalls. For example, when Digideck begins to consolidate its components into a single decoder unit or chipset with a shared power supply, its technology will become much noisier from crosstalk and shielding/coupling problems and will not likely be able to meet the level of performance permitted by its present bulky and expensive prototype. Similarly, it is not clear that the Digideck system has ever been tested under the high RF levels that actually exist at most transmitter sites. Moreover, Digideck has still not even begun to develop applications and the related software for its technology, much less acquired any real-world experience that would allow it to refine and expand its data broadcasting efforts.

The hurdles that Digideck faces are critical to evaluating a proposal for NTSC data broadcasting, since the FCC has already indicated that NTSC has a relatively short life span. To squander that valuable time while the clock is ticking away on NTSC broadcasting would not only be foolish, but might doom NTSC data broadcasting of any type, since broadcasters will be less likely with every passing year to invest additional amounts in their NTSC operations, particularly once they are suffering under the weight of expenses related to acquiring Advanced Television equipment. Data broadcasting as an industry now has a window of opportunity that may close before Digideck (even assuming it is ultimately successful in developing production equipment that performs well) ever gets to a position to step through it.

Out-of-Band Emissions. The laboratory tests highlighted a serious possible out-of-band emission problem that Digideck must confront. Moreover, the tests performed by the ATTC measured only the emissions generated by use of the Digideck exciter and did not test the exciter in actual transmitters to determine whether out-of-band emissions increased even further due to transmitter non-linearities. If it is ultimately determined that Digideck's system causes out-of-band emissions in excess of the FCC's legal limits, then further consideration of the Digideck system would be pointless.

Even slightly increased out-of-band emissions are very significant, since the advent of ATV will result in adjacent channel crowding of the spectrum. Because ATV transmitters will generally operate at lower power levels than existing NTSC transmitters, slight increases in out-of-band emissions could very well interfere with ATV signals and exceed the permissible signal ratios ultimately established by the FCC. Even if the Digideck system should turn out to comply with the ATV interference parameters eventually adopted by the FCC, the uncertainty existing until that decision is made will hinder further investment in, and development of, the Digideck technology. Given the amount of time and effort that will be necessary to create a marketable Digideck product, as well as the financial commitment needed from broadcasters to successfully launch the product, such uncertainty will likely delay development of the Digideck system until NTSC has already begun to be supplanted by ATV.

Inability to Integrate into a Network. One decision WavePhore made in designing its datacasting system was that in order for the system to be practical, it would have to utilize baseband video rather than a Digideck-type process of inserting data at the transmitter. An important advantage of the baseband approach is that it is much easier to integrate data transmissions into the broadcaster's overall distribution system. For example, the data can be inserted into the video signal at the studio and then relayed with the signal to the transmitter. In contrast, a system like Digideck's requires a broadcaster to either obtain FCC authorization for a microwave link (if the frequencies are available) to deliver the data separately to the transmitter so that it can be blended into the video at the transmitter site, or run a land line to the transmitter to relay the data. In either case, the broadcaster must pay to acquire and maintain the data link with the transmitter. Because the data in such a system is placed in a part of the television signal that does not exist until the signal passes through the television transmitter (the vestigial sideband), the Digideck system cannot be used in conjunction with satellite or microwave communications, and cannot be relayed by most television translators or cable television systems. Thus, while WavePhore can use a network satellite feed to relay data to every television station in the country, and then have the station's data/video signal carried along by microwave relays to distant locations as well as be transmitted over vast expanses by television translators, the Digideck system cannot even get the data to the satellite. The implications of such a limitation are profound. Moreover, the benefits of using a standardized, universal data transmission technology that is platform independent are substantial, not the least of which is the far greater ease with which economies of scale in equipment production can be reached when all portions of the video industry are using the same equipment.

Transmitter Modifications. Another problem of a non-baseband system such as that of Digideck is that it requires a broadcaster to go off the air or switch to an auxiliary transmitter in order to install a special exciter in its transmitter, whereas broadcasters using the WavePhore

system merely have to connect the encoding unit into the studio chain. If any problems occur, all a broadcaster using the WavePhore system has to do is walk into the studio and push the bypass switch. In contrast, broadcasters using the Digideck system will have to travel to their transmitter and shut it off while the Digideck exciter is being replaced with a standard exciter. Once the broadcaster has resolved whatever the problem is, it then has to shut off the transmitter again in order to reinstall the Digideck exciter.

FCC Approvals. Another reason for WavePhore's baseband approach is that, while the FCC has never overly concerned itself with the baseband equipment used by a broadcaster, it has always been very sensitive to anything which affects the way the transmitter and antenna operate. At a minimum, this means that the FCC will be closely monitoring stations that use a Digideck-style system to ensure that the altered transmitters operate within parameters and do not produce what the FCC considers to be unacceptable out-of-band emissions. Even if the FCC ultimately approves a broadcaster's data broadcasting operation, the risk that it will not do so may make many broadcasters very hesitant to invest in such a technology. Every time a transmitter is altered in such a fundamental manner, the broadcaster will likely have to obtain approval from the FCC to use a non-type certified transmitter, and provide extensive technical information on the altered transmitter before such approval can be obtained. If non-linearities in a particular transmitter do indeed result in excessive out-of-band emissions because of the Digideck exciter, then the broadcaster has either wasted its investment in the Digideck equipment or must purchase a new transmitter that is compatible with the Digideck exciter Neither is an attractive option.

Other Significant Technical Issues. In addition to the technical issues discussed above, there are several clear deficiencies in Digideck's technology, some of which have not been fully addressed in the laboratory tests. The issues raised with regard to the Digideck system include significant audio degradation and some video degradation. Digideck has proposed the remedies of using a brick wall filter between the audio and video signal and reducing the data injection level by 6 dB. Whether these proposed solutions do in fact remedy the cited degradation problems, each of them will generate ripple effects that will require retesting of the system as modified. The introduction of a brick wall filter is likely to affect such items as the chrominance information in the signal and thereby cause increased video degradation. Reducing the data injection level will adversely affect the robustness of the Digideck system. In short, the continuous evolution of the Digideck system throughout the testing process may or may not lead to improved performance in the areas of concern, but it will almost certainly lead to an altered overall performance that will have to undergo further testing to ensure that new problems have not been introduced.

Costs. Finally, because a broadcaster using a non-baseband data system has increased the number of studio to transmitter relays, moved the maintenance point for the data broadcasting equipment from the studio to a potentially remote transmitter site, and moved the focus of such maintenance from a stand-alone encoder to the very heart of its transmitter, the likelihood of a malfunction, the severity of a malfunction, and the cost of making repairs are all greatly increased. From a broadcaster's perspective, the non-baseband approach is fraught with unwanted difficulty and expense.

CONCLUSION

Based on the foregoing, WavePhore asks the members of the NDBC to authorize additional testing of both systems. It appears to be technically feasible and cost-effective to test both systems in the field, and important issues remain to be addressed in testing, including the concerns with Digideck's out-of-band emissions and the compatibility of the two systems.

WavePhore encourages the Committee as it goes forward to aim for the adoption of standards that will provide broadcasters with as wide a data pipe as possible. The wider the pipe, the better and more varied the applications, and the more viable the entire data broadcasting industry.

DIGIDECK COMMENTS TO NDBC EVALUATION WORKING GROUP FINAL REPORT 20 March 1995

Digideck wishes to indicate its considerable satisfaction with the planning, conduct and evaluation of the NDBC laboratory tests. We also wish to compliment the participants for the professional environment in which this initial phase of the standards process has taken place.

In the evaluation that you are reading, the results are clear that Digideck's D-Channel system showed outstanding and superior performance throughout the tests -- exhibiting substantial data robustness against all impairments while having minimal effect on its host or adjacent channels. With the one exception stated below, we fully agree with the Evaluation Working Group's conclusions and recommendations, and we look forward to proving the D-Channel's laboratory promise in a real-world field test.

A General Comment -- Limitations to the Prototype System

As with all early prototype systems, readers will understand there were certain minor aspects to Digideck's system which performed less well than might be desired. In these few cases, the losses resulted from our implementation approach -- taken primarily to show proof-of-concept -- and will be readily corrected during final product development.

To be more specific, our test system utilized commercially available equipments wherever possible, and laboratory-type proprietary circuits only as needed. Using available commercial equipment did not always allow us to obtain optimal parameter settings. For example, filters were almost always wider than would be used in circuits designed for the application. On the transmit side this resulted in more low-level out-of-band signal power than would appear in a final product, on the receive side it resulted in more input noise power than expected in a final product. Both effects slightly derated our test results.

Perhaps worse, utilizing multiple independent devices rather than a single integrated unit blocked application of certain signal processing features common to modern digital radios, such as the use of soft bit decision (Viterbi decoding) in the forward error correction process, and coordinated feedback to control AGC levels.

Technical readers will recognize that the above issues can be properly corrected in the product development phase without compromising some other system facet, thereby yielding improved performance in the final product. In the comments below we wish to highlight certain issues, and discuss those few minor points which were raised as areas of possible concern about the D-Channel system.

Items 1 and 2 -- Transmitted Bit Rate and Net Bit Rate

The Digideck system used DQPSK modulation at a 700 kbps channel rate, with rate 3/4 Reed-Solomon forward error correction, resulting in 525 kbps of measured "net bit rate".

It should be clear that there are many possible alternatives to a fixed data rate use of the channel, so that different users might elect to achieve different business objectives. Until the Committee determines how flexible a standard is desired, these parameters should be recognized as representative, but not necessarily final.

Item 3 -- Out of Channel Emissions

The specification for out-of-channel emissions is governed by FCC Regulation 73.687. In this specification, the out-of-band signal produced by a 30 IRE tone should be at least 40.56 dB below the video carrier's peak level, except at -3.58 MHz, where it must be 62.56 dB below.

The Evaluation Working Group has interpreted this specification to require that *all* out-of-channel components must be 40.56 dB below the peak carrier level of its host, except at -3.58 MHz, where they must be 62.56 dB down. We do not agree with this interpretation, since ordinary video can and frequently will exceed these levels simply by modulating by more than 30 IRE units. Further, we are not yet persuaded that running a spectrum analyzer in a peak hold mode gives a fair picture of the out-of-channel signal spectrum.[1]

Nevertheless, as noted in the evaluation report, *the ATTC plot shows that the Digideck signal meets the levels of this (conservative) interpretation*. Still, the narrowness by which the Digideck peak hold plot fell below the interpreted values suggested to some Working Group members that any further spectral spreading (e.g., from an actual transmitter) might cause the D-Channel signal to exceed the specifications. We claim this will not be a problem for the D-Channel final product, even if the report's interpretation proves valid.

There is nothing about D-Channel video and audio processing that should result in a wider spectrum than would be seen in any standard modulator. The only subject for legitimate concern is the data signal.

The D-Channel data signal is DQPSK, modulated at 350 k symbols/sec on a carrier 1 MHz and 30 dB below the picture carrier. *Suppose there were no filtering at all -- just the modulated signal*. Regardless of input, the modulated signal will have a sinc-function envelope to its voltage spectrum -- $\sin(\pi f/F_S)/(\pi f/F_S)$, where F_S is the symbol rate (350 kHz). If the signal is unmodulated, the result is a carrier of unity voltage. If the signal is binary modulated ±180° on

[1]Momentary tonal peaks 10 dB above the spectrum average can occur, but when they do the rest of the nearby spectrum drops to compensate. A peak hold plot masks this effect, implying that the entire spectrum is 10 dB greater than a plot in the power averaging mode would show

each symbol, the result is no carrier, and a decreasing series of tones at odd harmonics of half the symbol rate ($\pm nF_S/2$). The spectrum becomes a continuous smooth filling of the envelope if the input is random.[2]

At the assigned channel edge, f = 250 kHz, and the envelope level is -9.2 dB. Integrating the envelope equation from channel edge to infinity, the total unfiltered power outside the channel is 12.26 dB below the data carrier, or 42.3 dB below video. Even if this were accumulated into single tone it would not be a cause for concern, except at the -3.58 MHz point. *Thus the basic signal meets the interpreted requirement of 40 56 dB without any filtering whatsoever.*

With worst case modulation (±180°) the tone closest to -3.58 MHz is 7.5 symbol rates away from the data carrier, and is 27.4 dB below the total power in the data carrier, or 57.4 dB below the video carrier. *While not quite meeting the interpreted requirement of 62.56 dB (missing by 5.2 dB), it is clearly not a problem to meet the requirement with just a small amount of filtering.*

In the test system our data signal was generated and filtered at IF using a Comstream CM701, a commercially available satellite modem. The CM701 employs a digital 6-pole Butterworth filter that measured 3 dB down at the symbol rate (i.e., ±175 kHz from the data carrier), and 16.0 dB down at the edge of the video channel (Figure D-1), relative to the modulated carrier. While this is only 6.8 dB of filtering at the channel edge, as explained above it is enough to fully meet the interpreted FCC specification. In addition, the entire channel was then subjected to a broadband SAW, further assuring no out-of-channel emissions.

Clearly the final product can employ tighter filtering. Digital filters with twenty percent excess bandwidth are already used in high volume consumer products. A twenty percent excess bandwidth filter would eradicate any residual spectrum beyond 1.20 x the symbol rate, or ±210 kHz from the data carrier, well inside the channel.

Item 4 -- Coverage

While the FCC uses +64 dBu as a specification for achieving coverage to the Grade B contour, one should remember that this is an *average* level, and that another 15 dB of signal strength is needed at UHF to serve 90 percent of the subscribers at this range. And while the FCC adds 10 dB to represent the Grade A contour, this was to counter the known increase in impulse noise, a characteristic not handled well by the WavePhore system.

For a data service to have practicality, it must be competitive with other means of delivery. Whether we like it or not, this requires the data signal to be receivable under conditions which are known to cause poor television reception -- *margin beyond good video reception is mandatory.*

[2]The power in each harmonic tone will be spread over the interval between its neighbors.

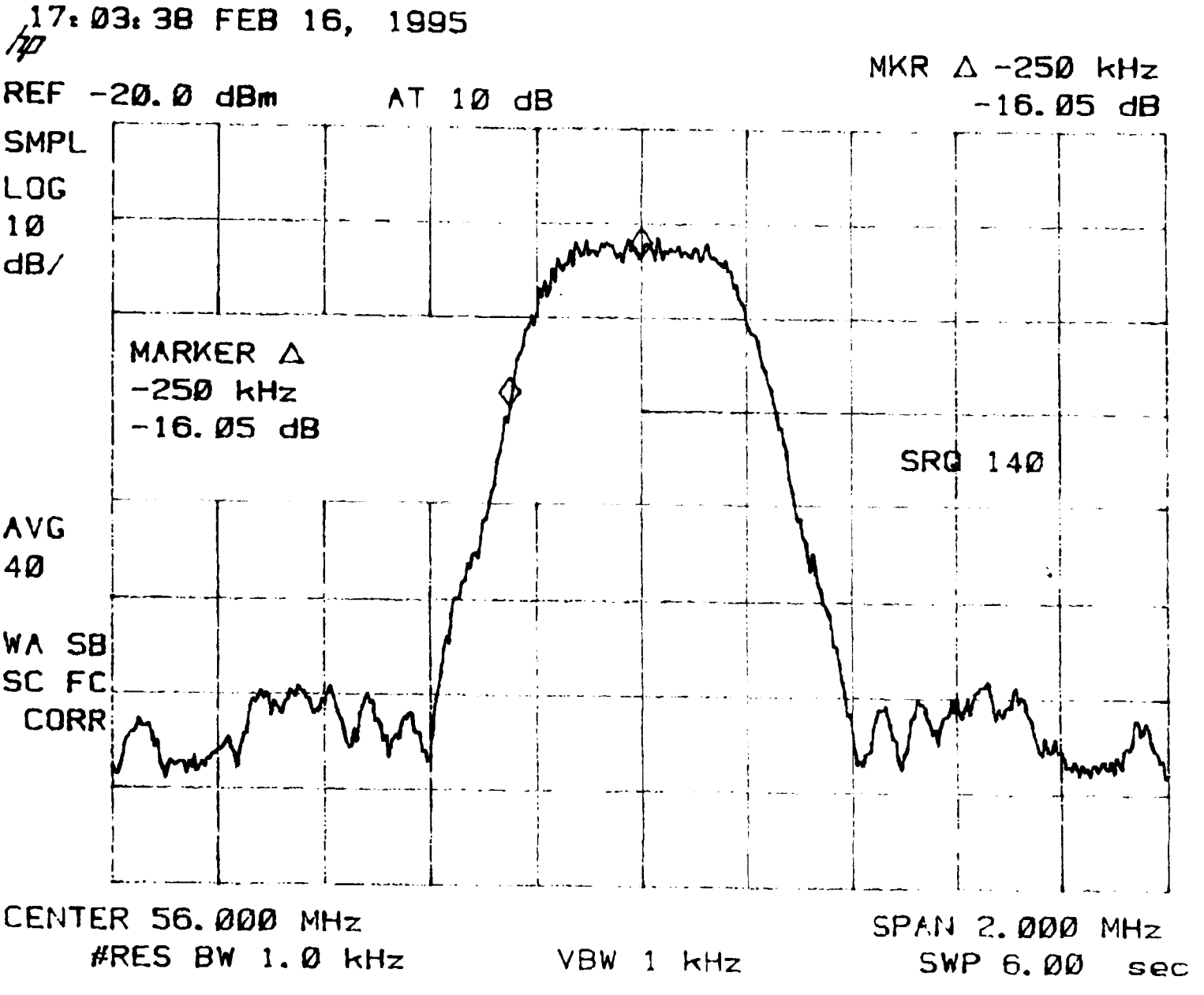


Figure D-1 -- Data Signal Generated by Comstream CM701

Item 5a -- NTSC Degradation (Video)

Visible degradation of the host video did not occur on most sets with the D-Channel signal. The few sets which were sensitive to our signal showed a slight increase in the background noise level in flat vision areas. This can be rendered totally invisible by lowering the injection level of the data carrier about 6 dB.[3]

Test results show the D-Channel data signal has 16 dB of margin beyond the level required for Grade B Contour coverage; up to 3 dB additional margin is anticipated in the final product. As a consequence, reducing the injection level by 6 dB is a realistic station option that can remove any concerns about picture quality.

Item 6 -- NTSC Degradation (Audio)

Minor audio degradation occurred as a background hum. We believe this was due to our failure to insert a brickwall filter between the video and the audio. The omission occurred as an implementation choice -- our modified exciter frequency shifts the modulated video against the VSB edge of a conventional SAW filter to create the space for the data carrier, and then restores the video to conventional IF without passing through another SAW. This will be corrected in the final product by investing in a custom SAW which will have the required VSB rolloff *and* the brickwall filter.

Moderate audio degradation occurred on one set with one test sample -- the glockenspiel on a set with a Hughes SRS sound processor. The source of this problem, if it is even considered a problem, remains under study.

Item 12a -- Random Noise into NTSC+Data

The final system is expected to have a 3 dB improvement in data immunity to noise over the tested system -- 1 dB due to use of properly matched filters, and 2 dB due to addition of soft bit decision.

Item 12b -- Impulse Noise into NTSC+Data

This issue, together with static and dynamic multipath, is considered the leading limitation to successful urban operation, and is one of the most important places to establish better performance than cellular systems. We consider it very significant that the D-Channel signal survived up to the point of unusability of the host video.

[3]Demonstrated to ATTC personnel in unofficial, private tests conducted after the NDBC tests.

Item 15 -- Data Immunity to Static Multipath

See comment to impulse noise above.

Item 16 -- Data Immunity to Dynamic Multipath

The requirement to handle dynamic multipath is not limited to mobile applications -- wireless LAN's are finding dynamic multipath a critical issue for their systems due simply to having people move about in an office. Both indoor and outdoor reception will have to deal with this problem, and it should be considered a very significant decision factor.

Digideck's ability to handle large and small levels of multipath indicates its ability to succeed in an urban environment.

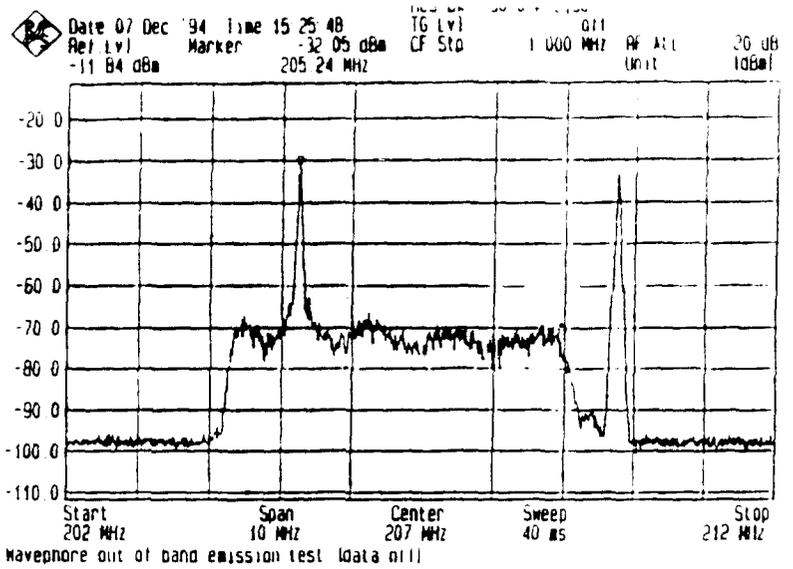
A Final Comment

Digideck believes that the results of these tests show conclusively that the D-Channel system:

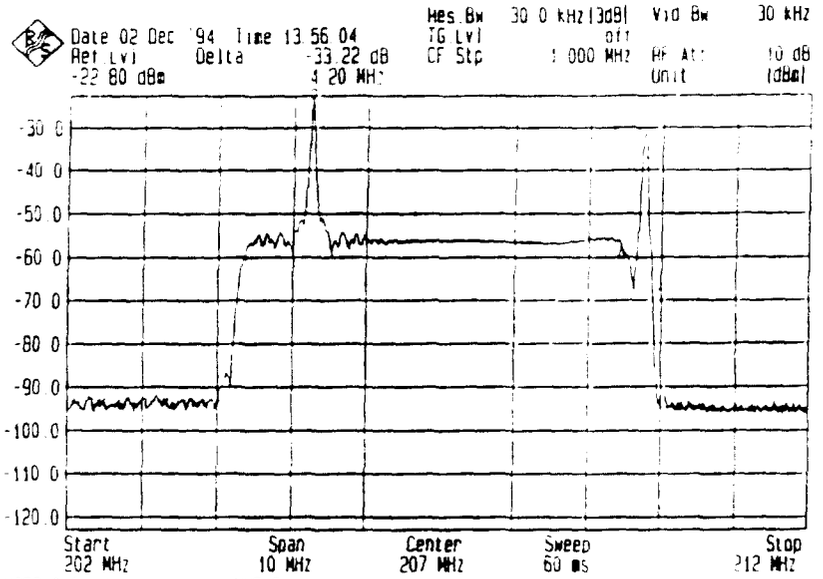
(a) is superior in all respects to competing methods, and
(b) is suitable for over-the-air applications.

We encourage reviewers to reach the same conclusions.

Annex 2 : Figures

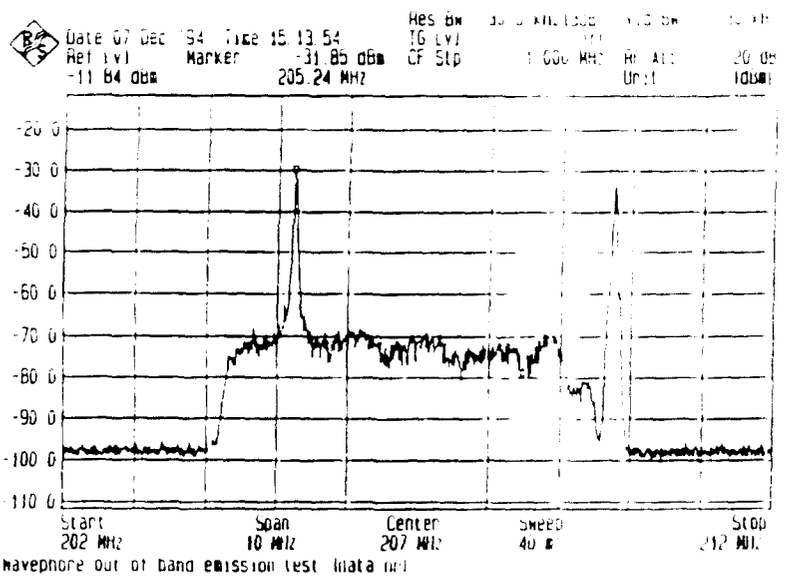


Out-of-Band Emissions
Data OFF 15:25:48

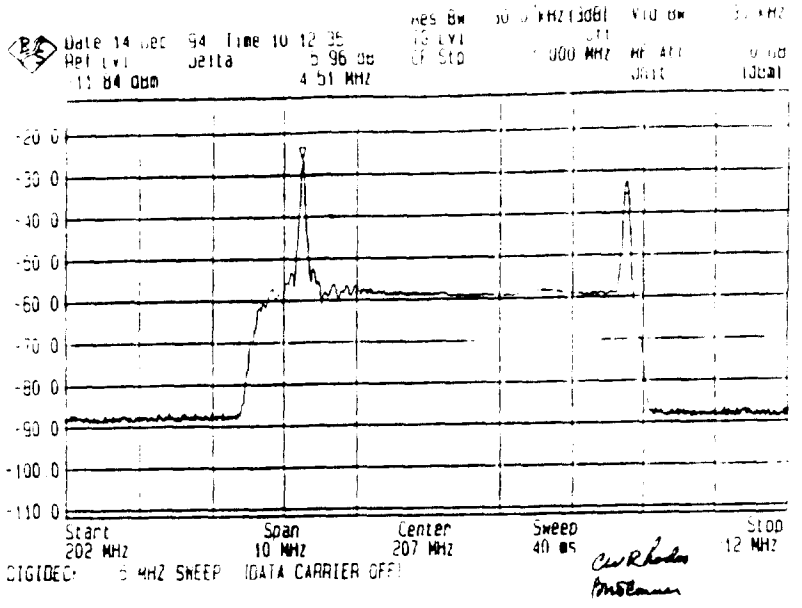


NTSC Reference Plot

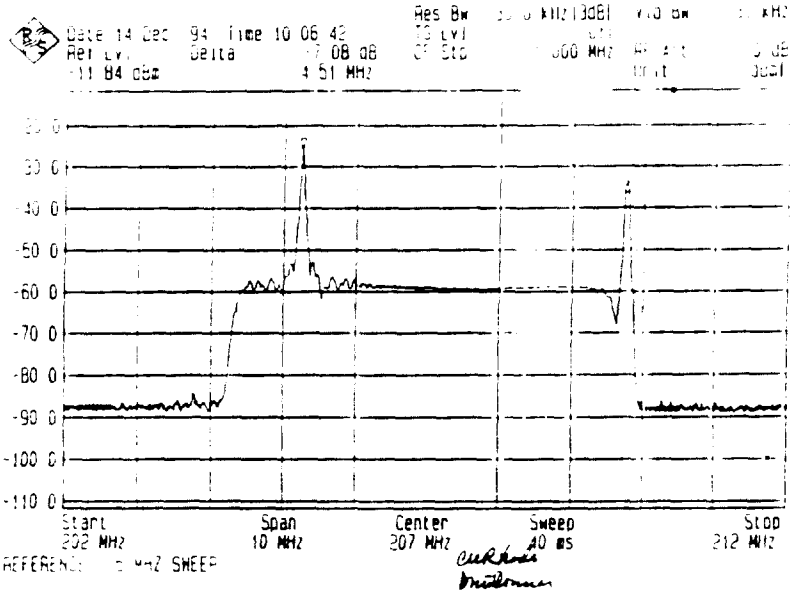
Out-of-Band Emissions
REFERENCE 13:56:04 (2-Dec-



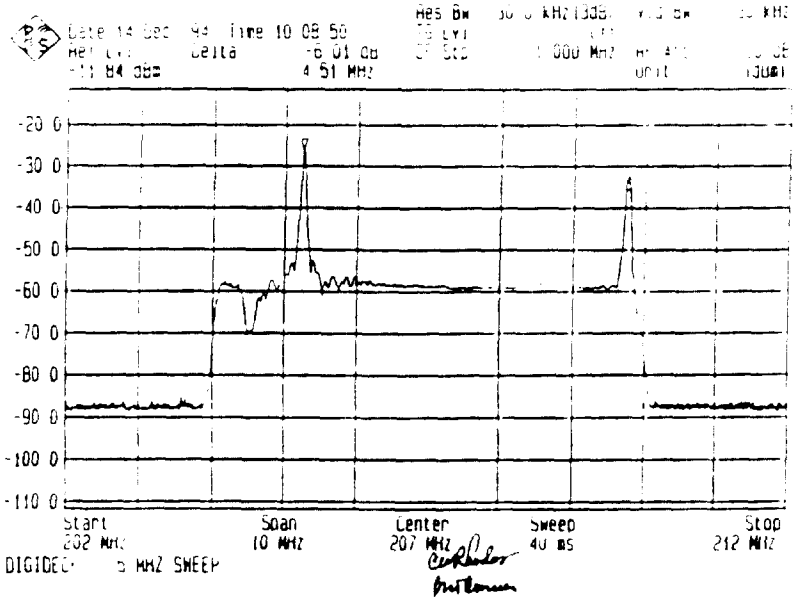
Out-of-Band Emissions
Data ON 15:13:54



Out-of-Band Emissions
Data OFF 10:12:35



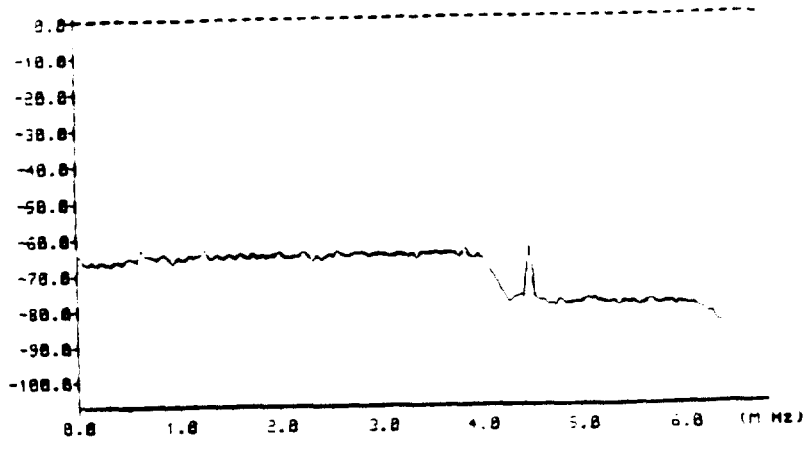
Out-of-Band Emissions
REFERENCE 10:06:42



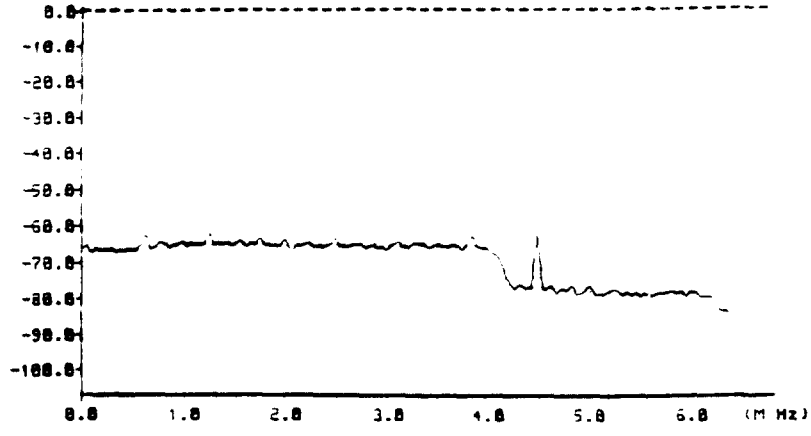
Out-of-Band Emissions
Data ON 10:08:50

Digideck
14-Dec-94

3.1.2 Out-of-Band Emissions Test

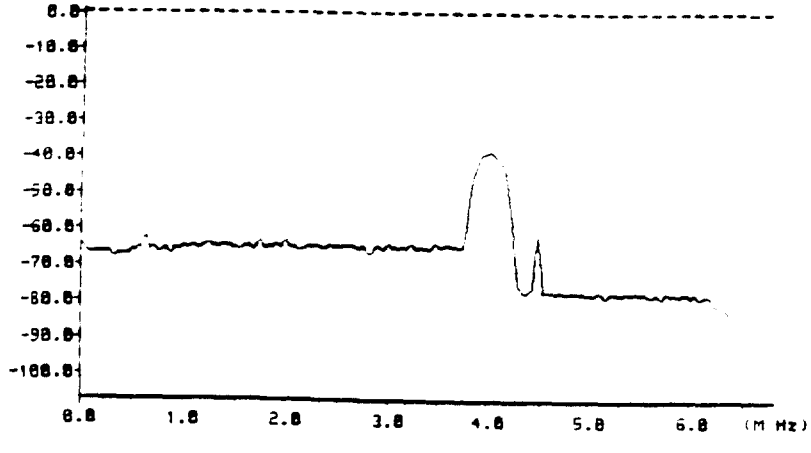


Data OFF 14:03:42



REFERENCE 13:36:49

Exciter: Harris Corp. Demodulator Tektronix 1450. Input to Demodulator -26 dBm. Noise floor or test setup and video bandwidth of Exciter and Demodulator shown.

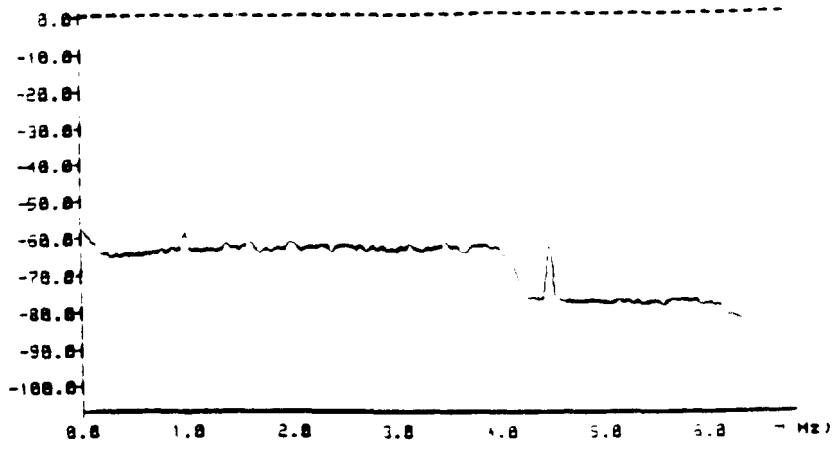


Data ON 13:56:40

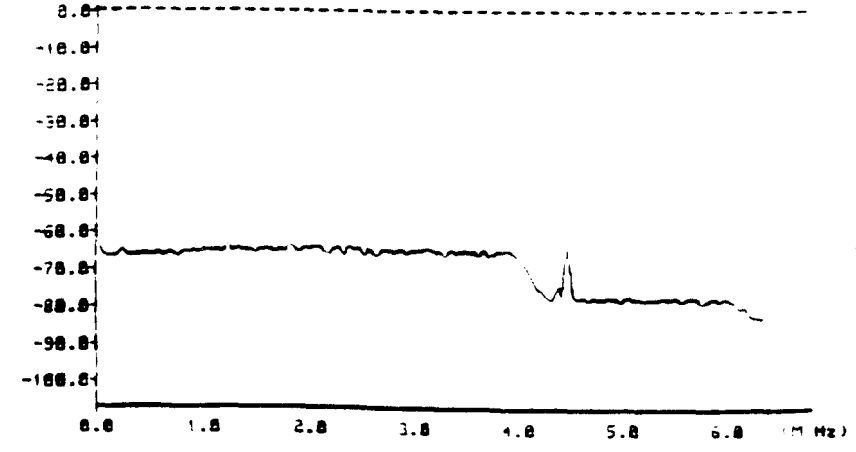
WavePhore 3.1.1 Objective Test Results 29-Nov-94

Strong Power Level -26 dBm

Noise Spectrum

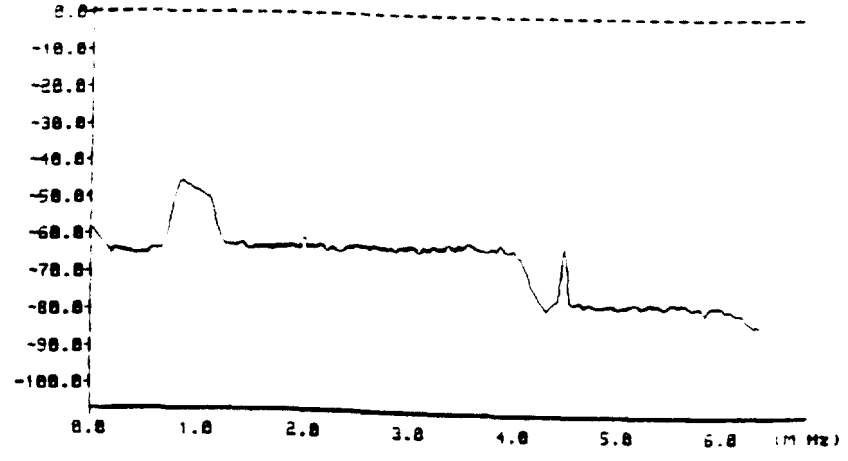


Data OFF 13:58:45



REFERENCE 13:51:36

Exciter: Harris Corp. Demodulator Tektronix 1450. Input to Demodulator -26 dBm. Noise floor of test setup and video bandwidth of Exciter and Demodulator shown.

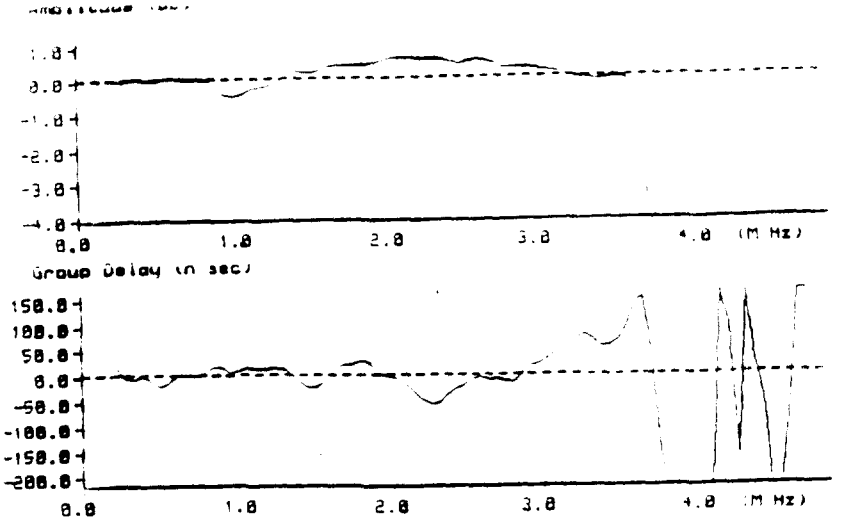


Data ON 14:04:56

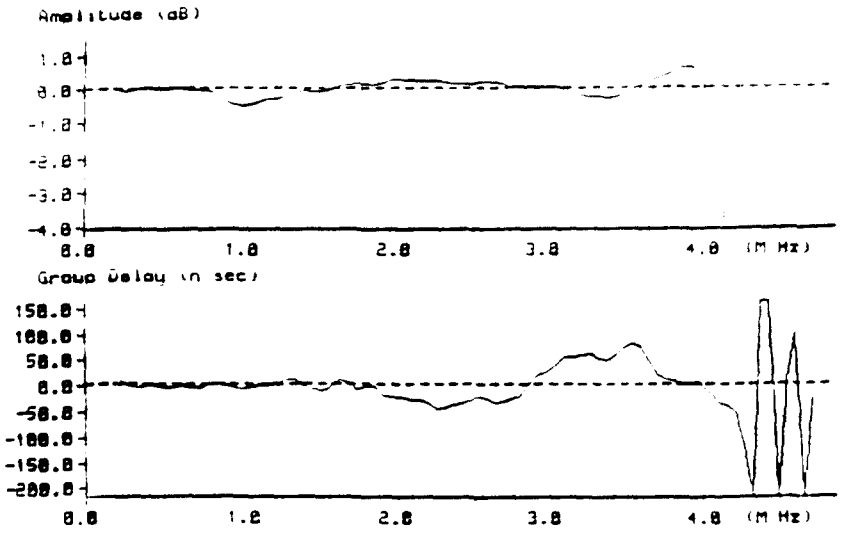
Digideck 3.1.1 Objective Test Results 14-Dec-94

Strong Power Level -26 dBm

Noise Spectrum

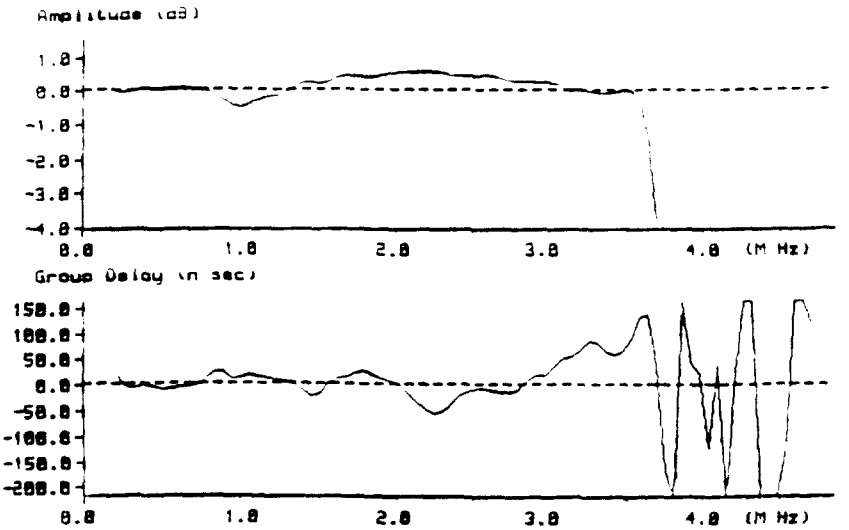


Data OFF 14:05:51



REFERENCE 13:41:25

Video bandwidth is limited by the Exciter and Demodulator as shown. Group delay at frequencies above video passband is due to the filters in Exciter and Demodulator. REFERENCE exciter: Harris Corp., Demodulator: Tektronix 1450.

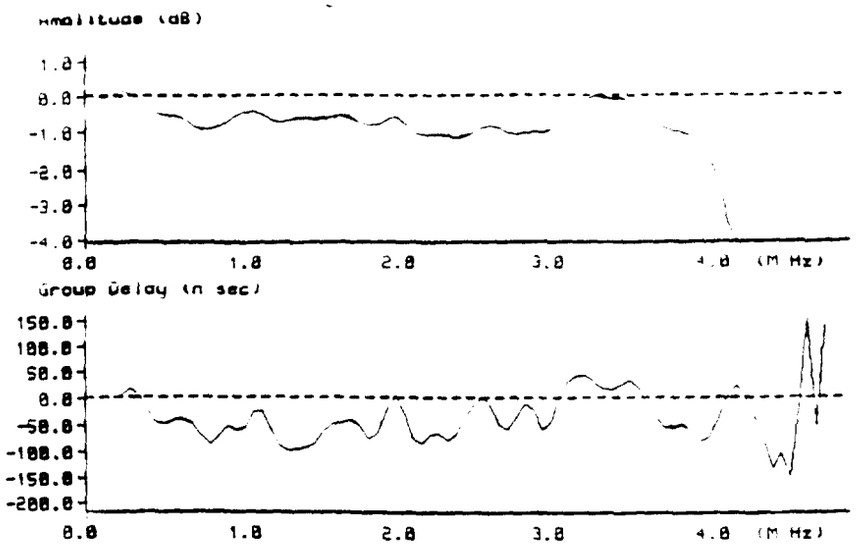


Data ON 13:58:30

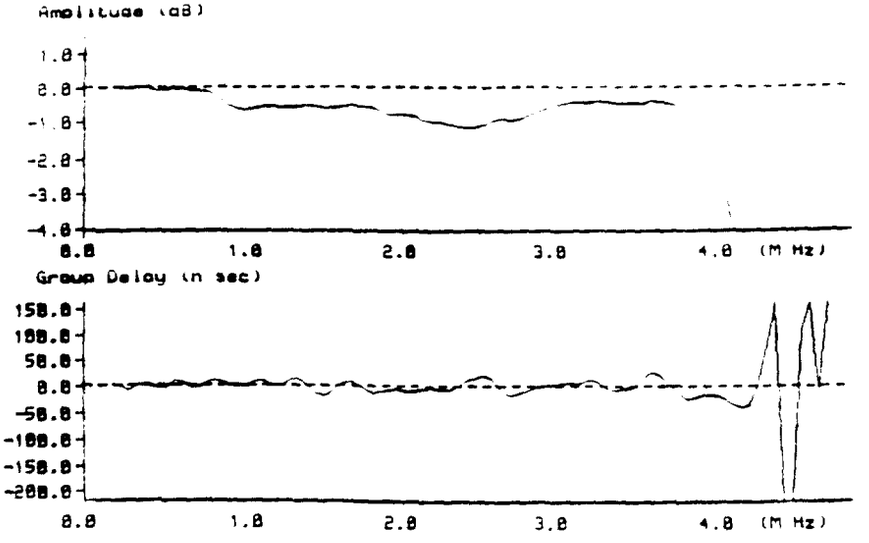
WavePhore 3.1.1 Objective Test Results 29-Nov-94

Strong Power Level -26 dBm

Gain and Group Delay as Function of Frequency

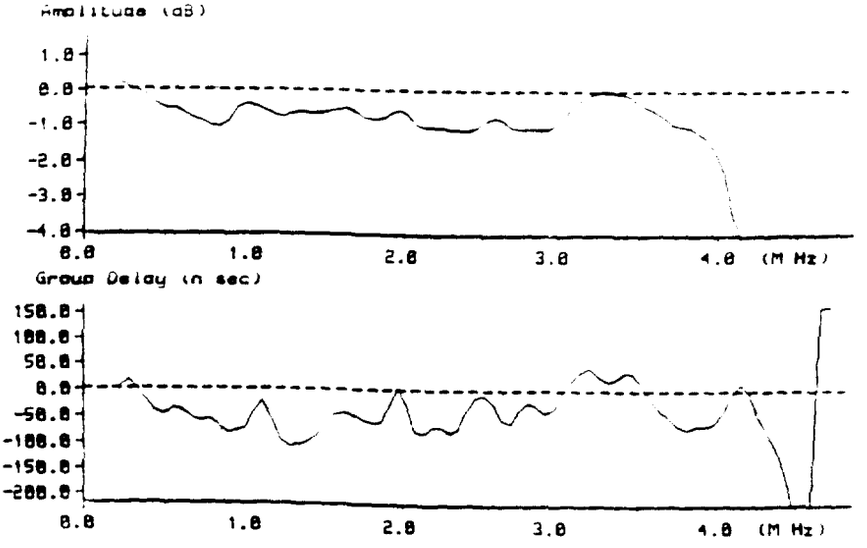


Data OFF 14:01:44



REFERENCE 13:55:48

Video bandwidth is limited by the Exciter and Demodulator as shown. Group delay at frequencies above video passband is dt to the filters in Exciter and Demodulator. REFERENCE exciter: Harris Corp., Demodulator: Tektronix 1450.



Data ON 14:07:50

Digideck 3.1.1 Objective Test Results 14-Dec-94

Strong Power Level -26 dBm

Gain and Group Delay as Function of Frequency